Defining deep decarbonization pathways for Switzerland: An evaluation based on GEMINI-E3

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The Deep Decarbonization Pathways Project

- Collaborative initiative to understand and show how individual countries can transition to a low-carbon economy and how the world can meet the internationally agreed target of limiting the increase in global mean surface temperature to less than 2°Celsius
- Managed by the Sustainable Development Solutions Network and the Institute for Sustainable Development and International Relations
- The DDPP comprises 16 countries: Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, South Africa, South Korea, the UK, and the USA
- http://unsdsn.org/what-we-do/deep-decarbonization-pathways/

Objective of the DDPP

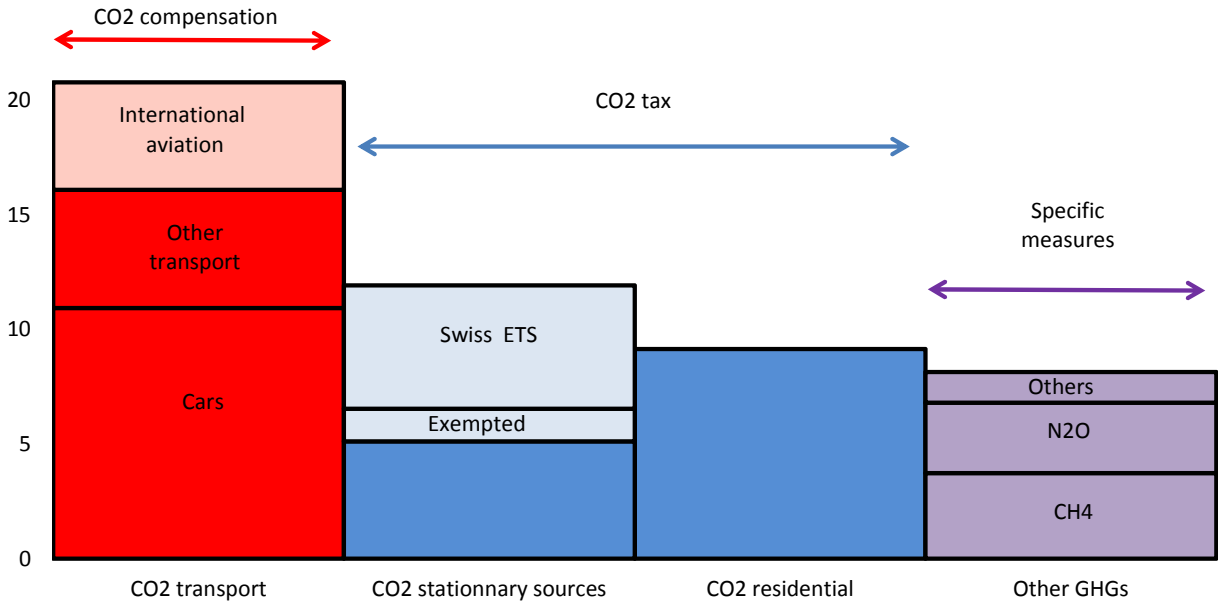
- Explore national pathways to 2050
- Consistent with the 2°C global carbon budget
- Technologically transparent
- Sectorally disaggregated
- Consistent with physical constraints (e.g. geological potential for CCS, technical potential for renewables)
- Provide basis for socio-economic impact analysis and policy implementation

Swiss contribution to DDPP

- Swiss administration decided to contribute to the DDPP
- A working group is dedicated to this task and managed by the Federal Office for the Environment
- INFRAS and EPFL are in charge to elaborate the Swiss DDP
- The Swiss climate target assumes a CO_2 emissions target of 1 ton per Swiss inhabitant in 2050
- The GEMINI-E3 model is used for the modeling part

Swiss CO_2 law

Target: -20% wrt 1990 levels for all GHGs
GHG emissions: 50 Mt-eq CO_2



- Stationary sources $\rightarrow$ CO_2 tax (current level 60 CHF), but exemption and Swiss ETS
- Subsidies on buildings refurbishment and renewable energies
- Transport: motors fuels compensation 2% (10% in 2020) of CO_2 emissions + performance standards for new cars

The GEMINI-E3 model

- World computable general equilibrium model
- Dedicated to the analysis of climate change & energy policies
- Recursive dynamic model
- Closure rules: Trade balances cleared, Government budget cleared, exogenous labor supply
- All GHG emissions
- Database GTAP 8 (2007)
- gemini-e3.epfl.ch

The two storylines

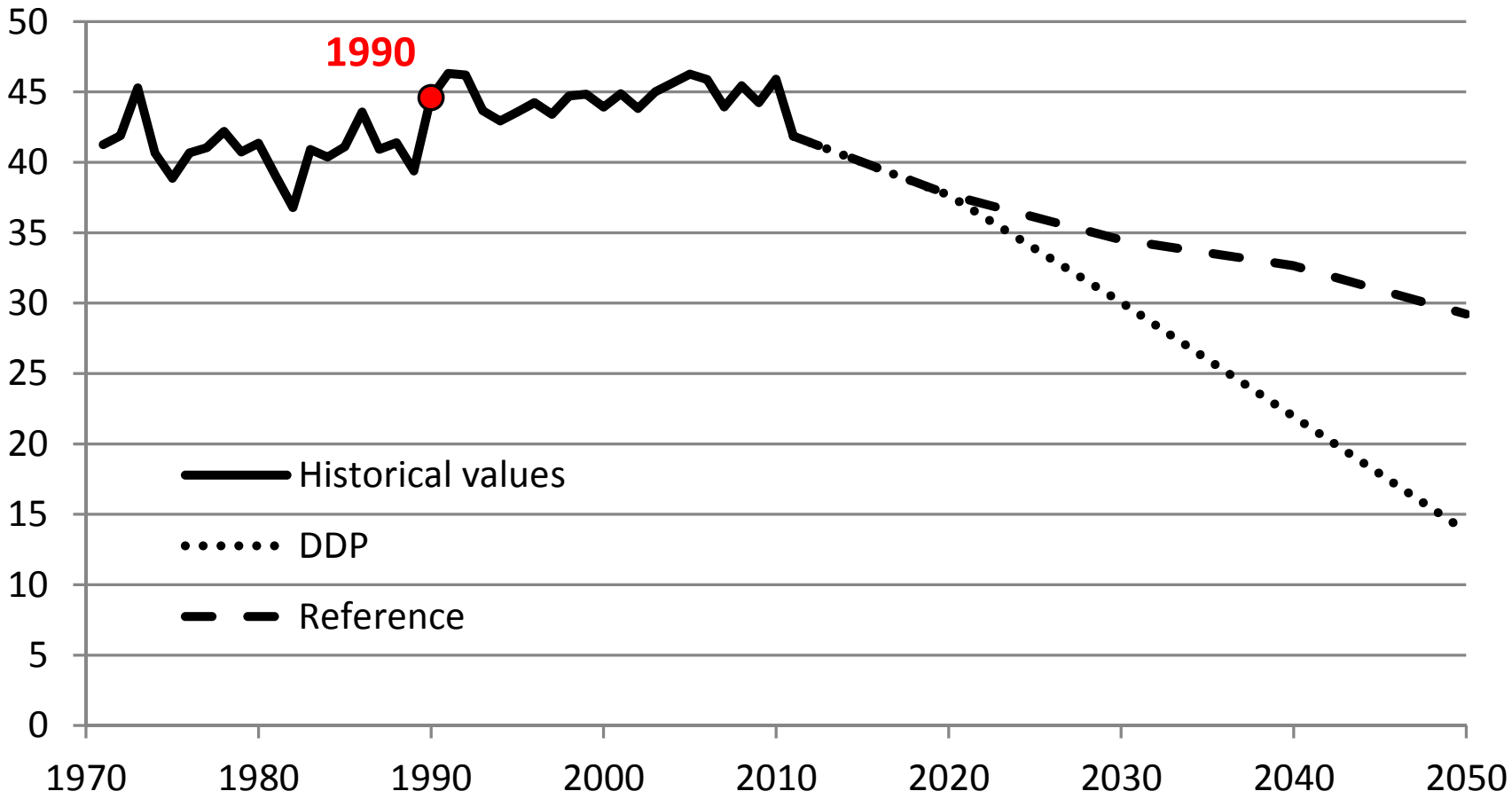
- The first one, called "reference scenario", assumes that Switzerland will reach a 20% reduction of GHG emissions relative to 1990 levels by 2020, using instruments that have already been defined. After 2020, we suppose that no additional policy will be implemented but the existing instruments would remain applied with their 2020 levels

- The other ones, called the "DDP scenarios", assume that Switzerland will reach by 2050 a CO_2 emissions target equal to 1 ton of CO_2 per inhabitant

Assumptions after 2020

- Reference scenario
  1. The carbon prices (ETS price, CO_2 tax) and levy charged on fuels for transport remain constant and equal to their 2020 levels
  2. The buildings refurbishment program remains constant at its 2020 levels
  3. CO_2 emissions standard for new cars remains constant at its 2020 levels
- DDP scenarios
  1. CCS option becomes available in 2025, price $\simeq$ 100 \$ per ton of CO_2
  2. The buildings refurbishment program is removed after 2020
  3. The CO_2 prices (ETS price, carbon tax) and the levy charged on fuels for transport are replaced by a uniform carbon tax applied to all energy consumption and set at a gradually rising rate sufficient to reach the CO_2 target by 2050

Swiss CO_2 emissions in the two scenarios in Mt CO_2



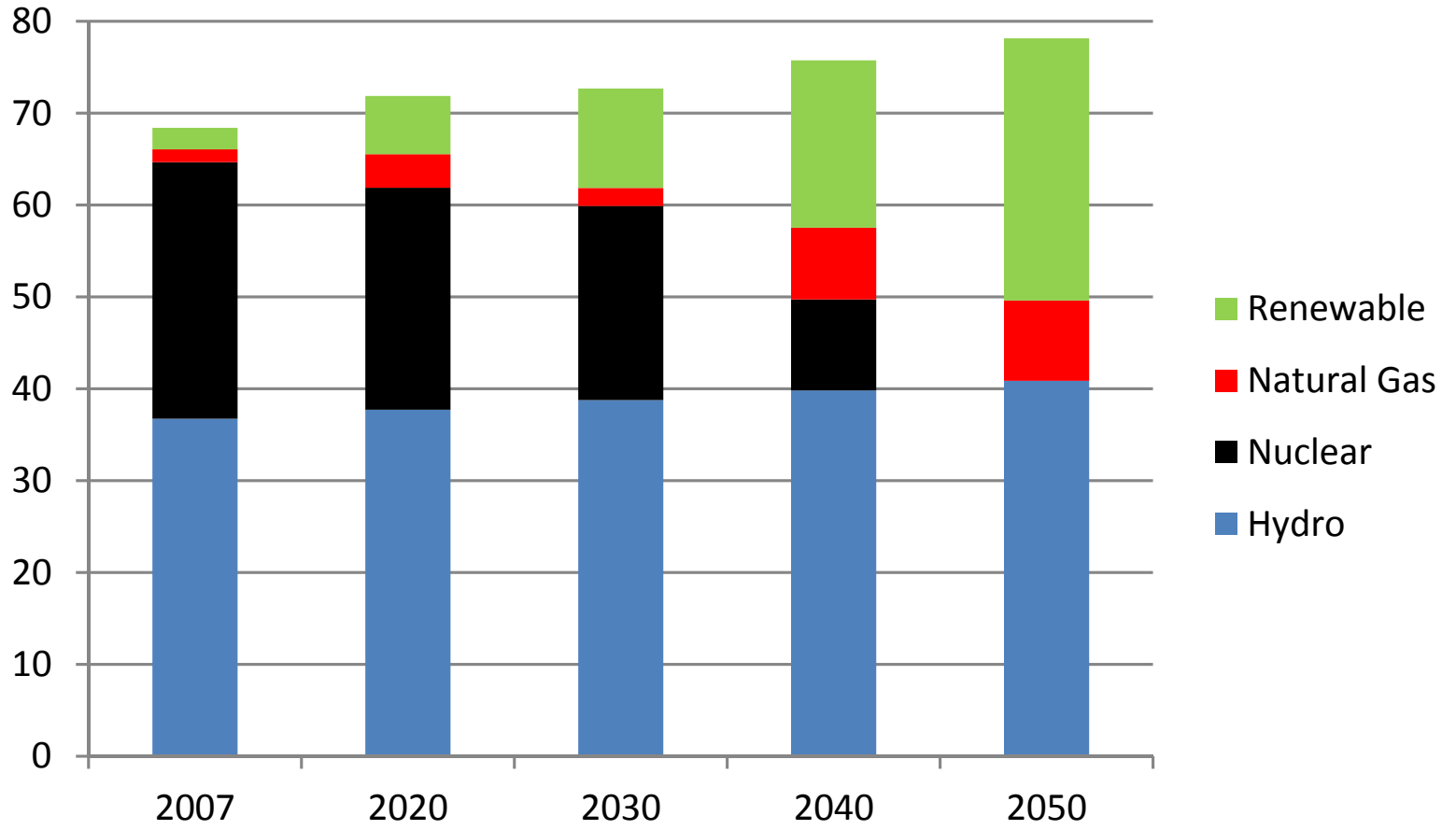
Reference scenario: CO_2 prices

Table: CO_2 prices and other levy in CHF_{2013} - Reference scenario

	2020	2030	2040	2050
CO_2 tax	60	60	60	60
CO_2 ETS price	40	40	40	40
Levy on fuel transport	0.02	0.02	0.02	0.02

In 2050, CO_2 emissions = -34% wrt 1990 levels

Reference scenario: Electricity generation in TWh



Nuclear $=$ 27 TWh

Max new renewable potential $\simeq$ 27 TWh

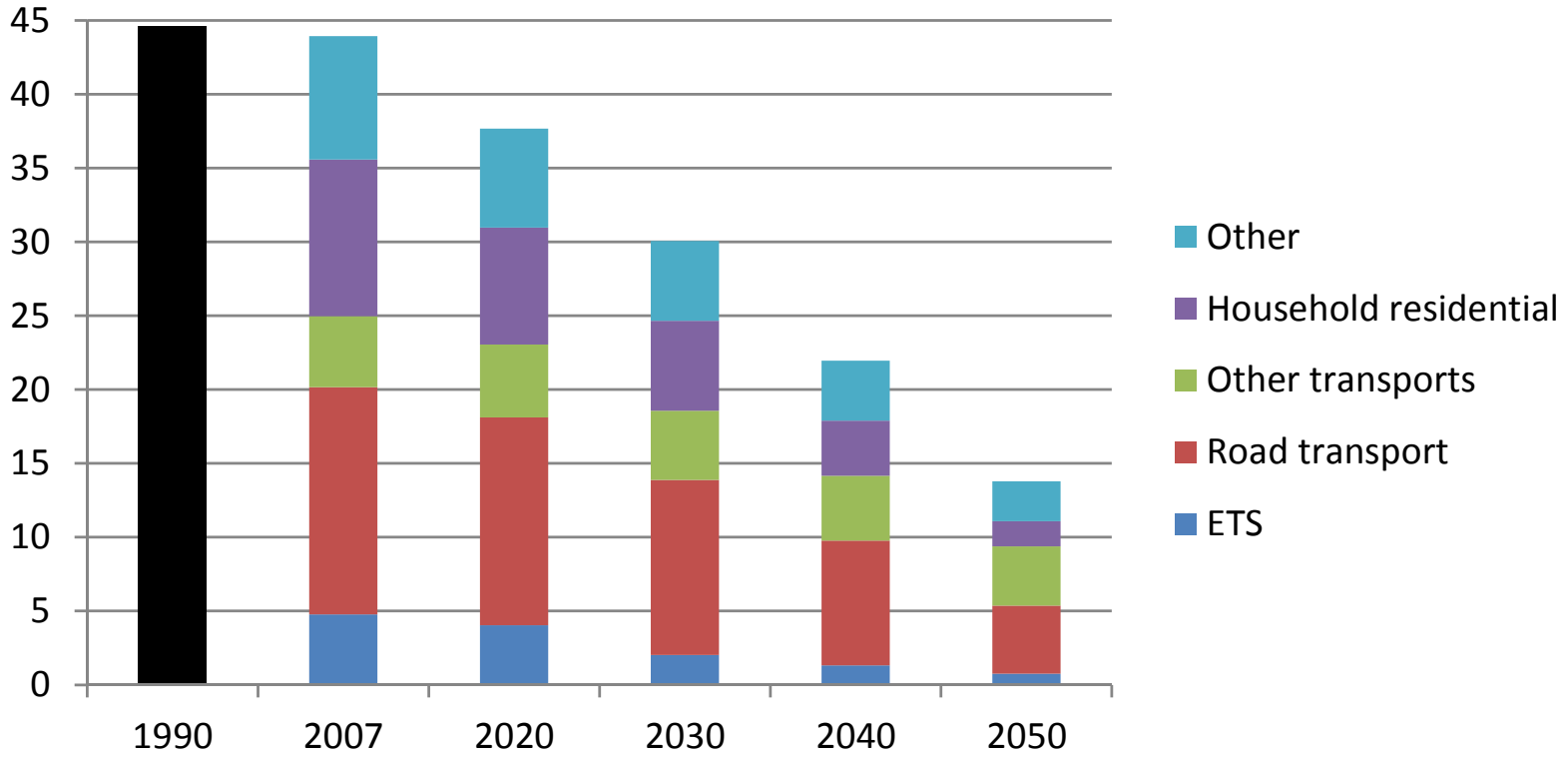
DDP scenario: CO_2 tax and welfare cost

Table: CO_2 prices and other levy in CHF_{2013} - DDP scenario

	2020	2030	2040	2050
CO_2 tax	60			
CO_2 ETS price	40			
Levy on fuel transport	0.02			
Uniform CO_2 tax		257	654	1556
Welfare cost in % of HC		0.4%	0.9%	1.7%

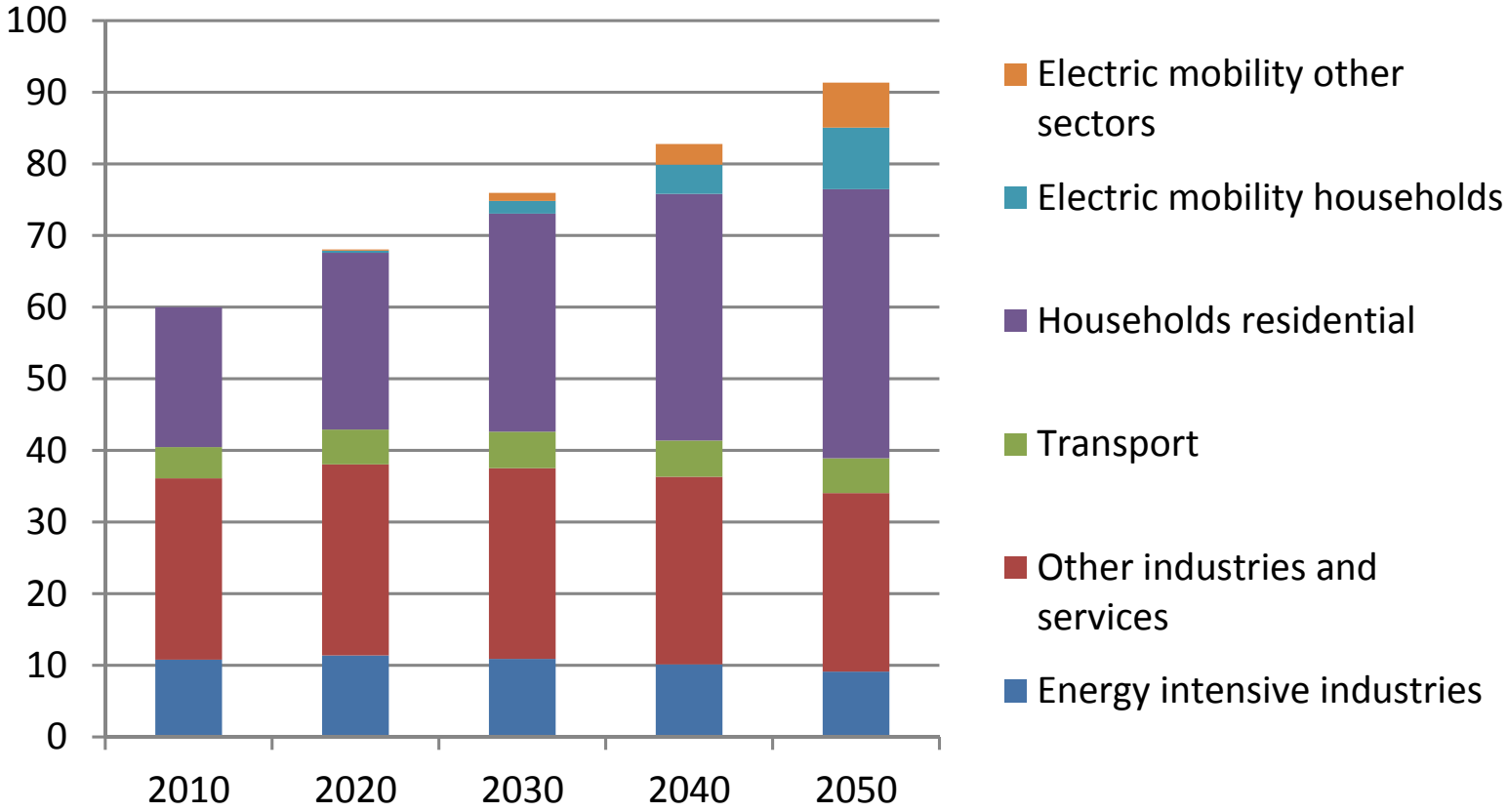
HC: Household consumption

DDP scenario: CO_2 emissions in Mt CO_2



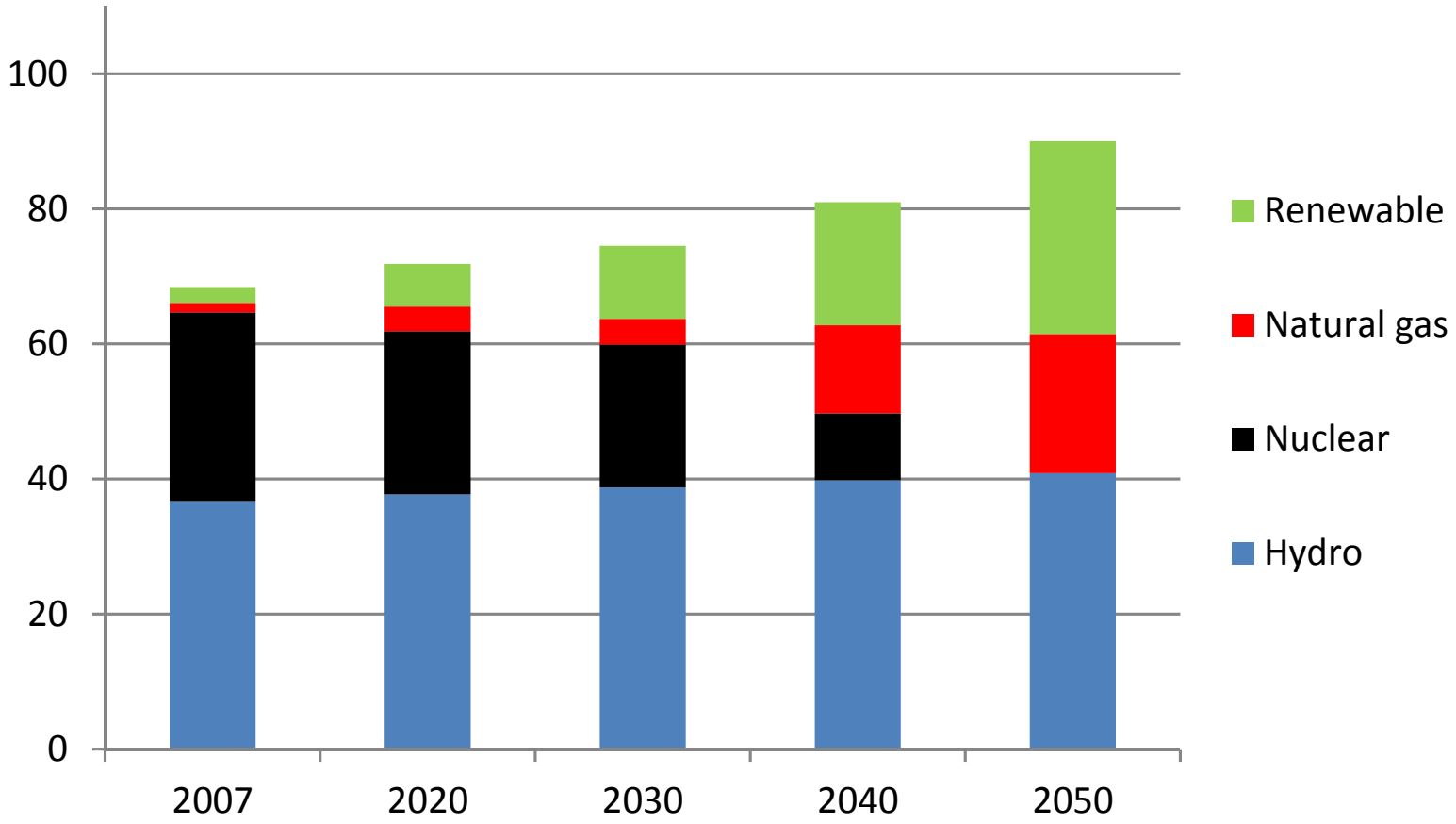
In 2050:
ETS -81%, Residential -78%, Road trans. -67%, Other transports -19%

DDP scenario: Electricity consumption in TWh



In 2050, Electricity consumption +15%, +12 TWh (+6 TWh electric mobility)

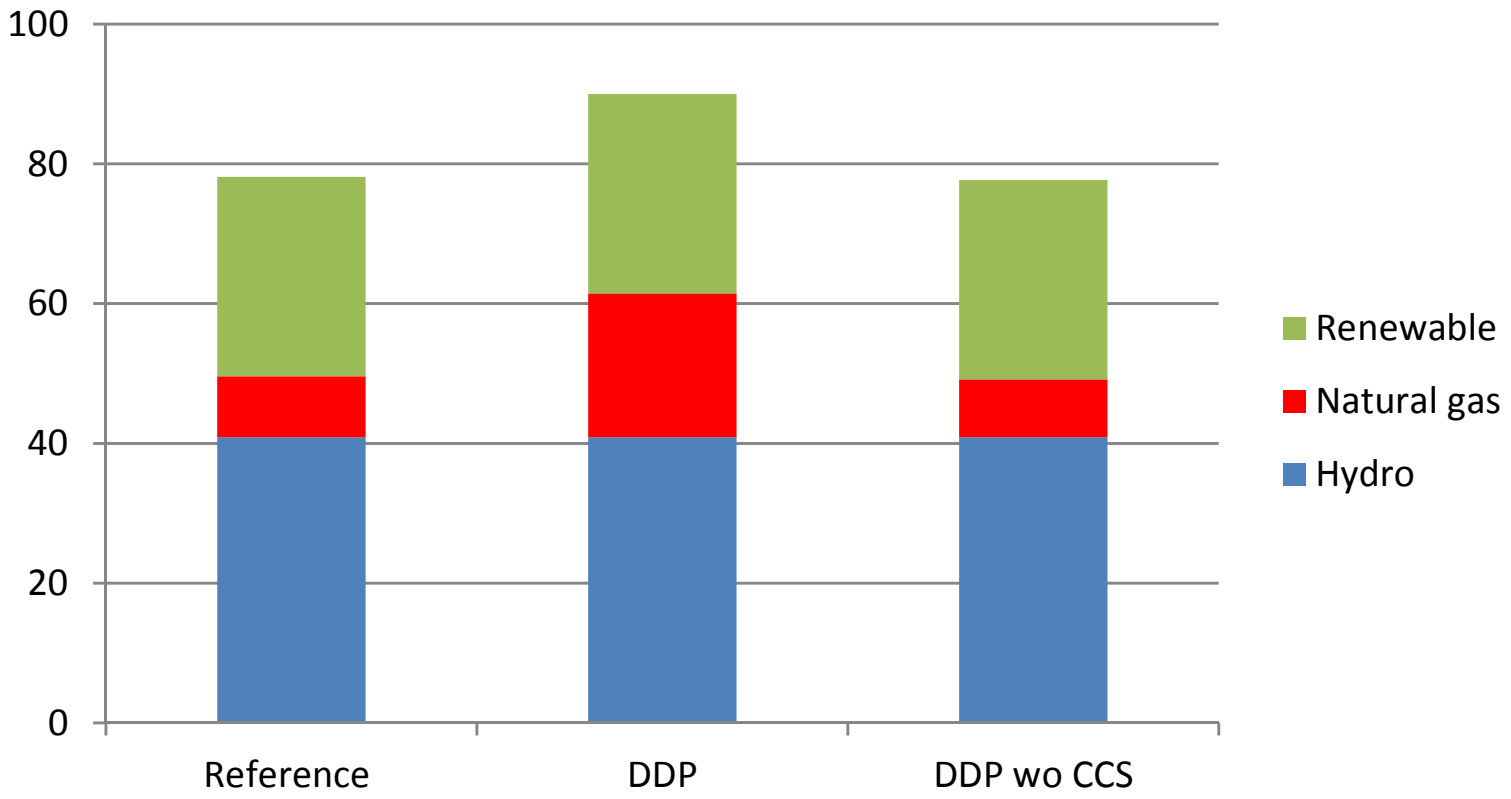
DDP scenario: Electricity generation in TWh



DDP scenario and CCS

- In 2050, 21 TWh produced with natural gas with CCS
- 2025-2050: CO_2 sequestered $=$ 77 Mt of CO_2
- But uncertainties surrounding CCS (technological, feasibility...)
- Social acceptability ?
- Energy intensity -45% wrt 2010 but electricity $+15\%$
- $\mapsto$ Try to run a scenario without CCS or with a constraint on electricity consumption

Electricity generation in TWh - year 2050



DDP scenario without CCS: CO_2 tax and welfare cost

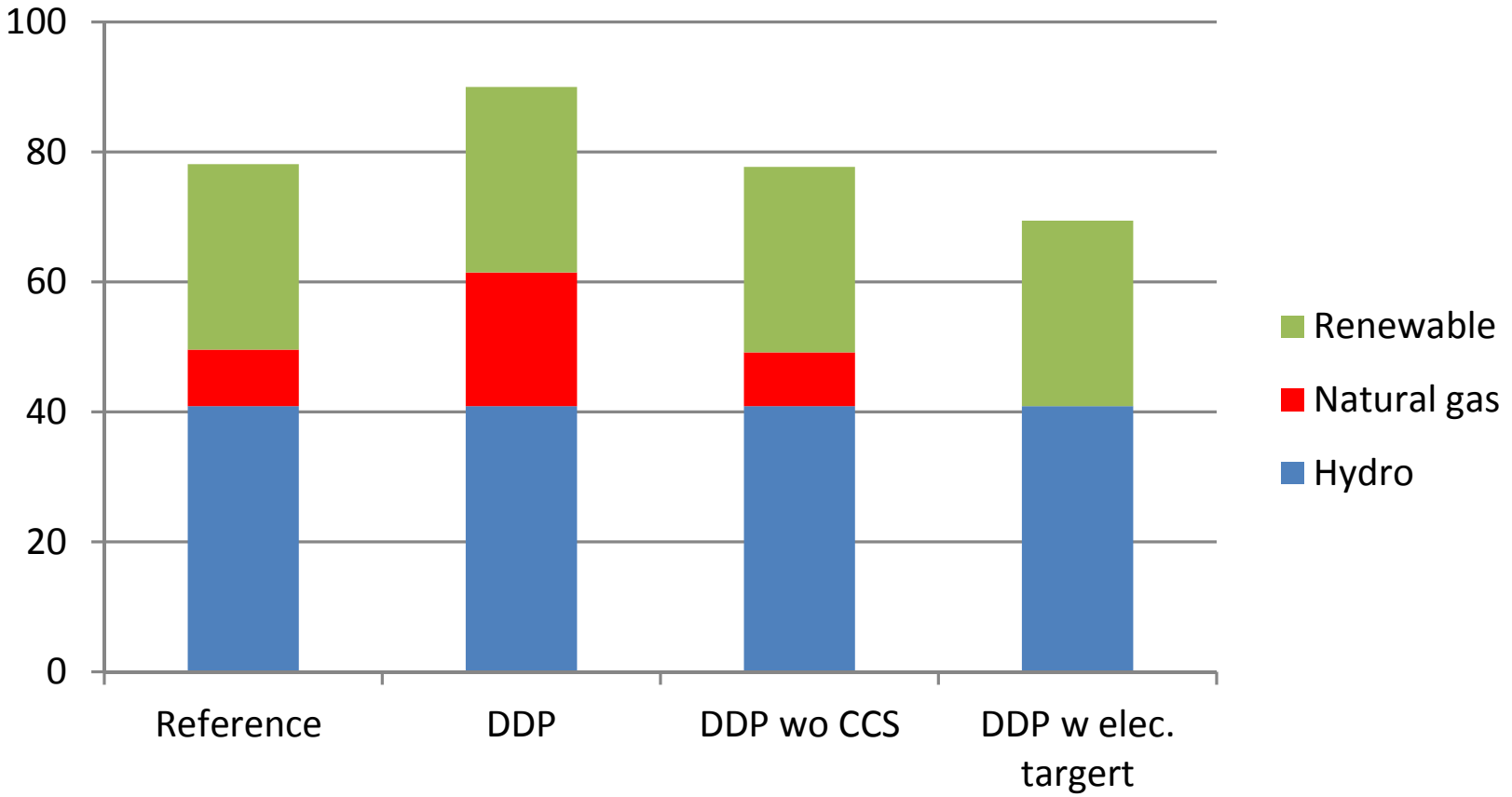
Table: CO_2 prices and other levy in CHF_{2013} - DDP scenario without CCS

	2020	2030	2040	2050
CO_2 tax	60			
CO_2 ETS price	40			
Levy on fuel transport	0.02			
Uniform CO_2 tax		324	1040	2652
Welfare cost in % of HC		0.4%	1.0%	1.9%

DDP scenario without constraint on electricity consumption

- Planned amendment of the Swiss Energy Act $\rightarrow$ target on electricity consumption per capita -3% in 2020 and -13% in 2035 wrt 2000 levels
- 2050: -18% wrt 2000 levels
- in 2050 $\simeq$ 63 TWh
- New tax on electricity consumption

Electricity generation in TWh - year 2050



DDP scenario with a constraint on electricity consumption: CO_2 tax and welfare cost

Table: CO_2 prices and other levy in CHF_{2013} - DDP scenario with a constraint on electricity consumption

	2020	2030	2040	2050
CO_2 tax	60			
CO_2 ETS price	40			
Levy on fuel transport	0.02			
Uniform CO_2 tax		299	787	1963
Electricity tax		18%	41%	88%
Welfare cost in % of HC		0.4%	0.6%	1.5%

Conclusion

1. It is possible to reduce Swiss CO_2 emission to 77% below 1990 levels
2. The cumulative cost is estimated to around 1% of household consumption
3. This pathway requires significant changes in all energy consuming sectors (building, industry, transport)
4. The pathway requires significant deployment of new technologies with new infrastructures, our modeling exercice use optimistic assumptions (without technical barriers)
5. The Swiss nuclear moratorium creates this DDP scenario very challenging with a high deployment of renewable (non dispatchable generation) in electricity generation
6. We propose two different pathways: with/without electricity increase